

THE PERFORMANCE OF THE NCEP OPERATIONAL MODELS FROM AN HPC PERSPECTIVE

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Understanding the performance of the operational model is critical to being able to forecast the sensible weather

- All models have strengths and weaknesses.
- All have trouble handling smaller scale features.
- All have problems with convection.
- All do a decent job in handling the short range (0-36 hr) forecast of synoptic scale features.

Why models have forecast problems

- Initialization and quality control smooth data fields, but some of the lost detail may be important.
- Lack of data over the oceans and Mexico.
- Atmospheric processes are non-linear; small changes in initial conditions can lead to large forecast variations (this is the basis for ensemble forecasting).
- Model physics are approximations
 - ◆ for lower resolution models, convection is parameterized
 - ◆ for higher resolution models the micro-physical processes are parameterized

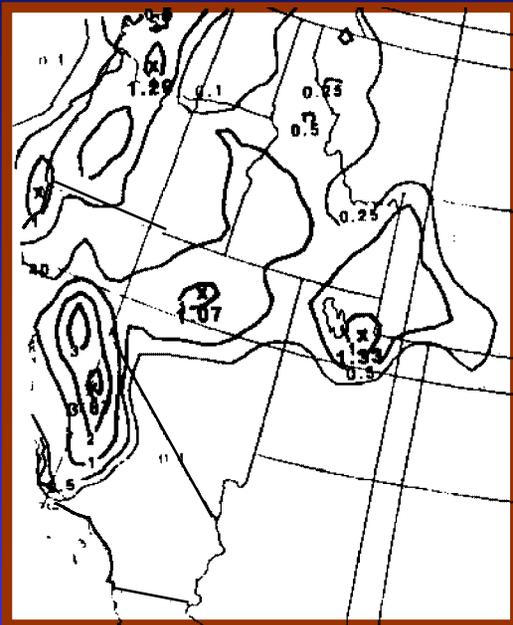
The way the physics are approximated can lead to model errors, for example

- The Betts parameterization in the eta is handled differently over land and water
 - ◆ this can cause the eta and meso-eta to erroneously strengthen the coastal front.
 - ◆ and to forecast too much rain along the Gulf and Atlantic Coastal regions

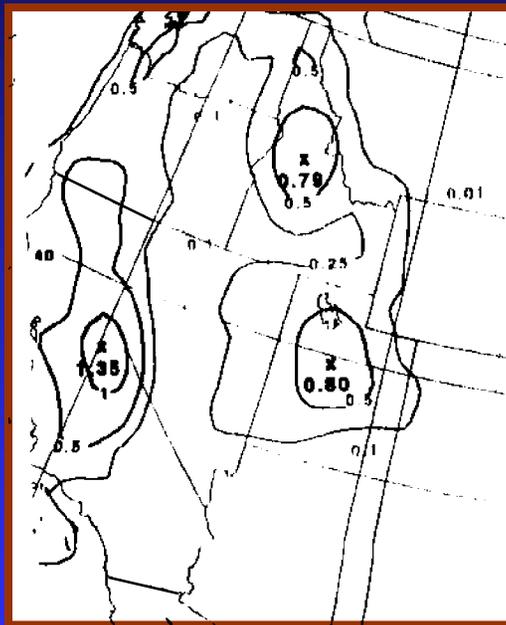
ETA MODEL IS BEST

- AT HANDLING ARCTIC AIRMASSES PLUNGING SOUTHWARD ALONG THE FRONT RANGE OF THE ROCKIES
- FORECASTING PRECIPITATION ALONG THE WEST COAST INCLUDING THE CASCADE AND SIERRA RANGES
- USUALLY BEST IN FORECASTING COLD-AIR DAMMING ALONG THE EAST COAST (ITS LI FORECAST IS OFTEN THE BEST INDICATOR)

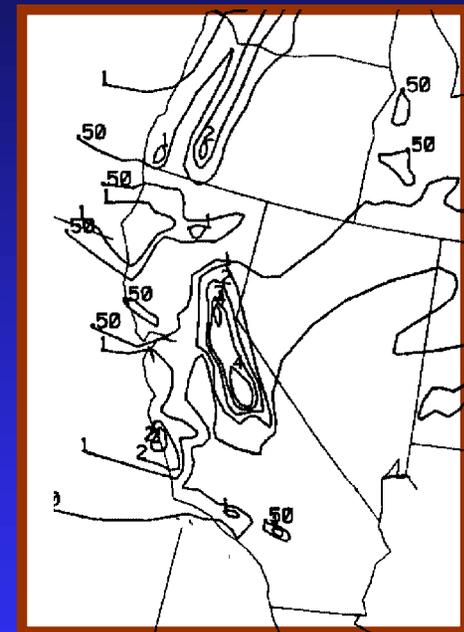
ETA IS BETTER AT FORECASTING PRECIPITATION OVER COMPLEX TERRAIN



12-36 H ETA V.T. 12Z 3 JAN 97



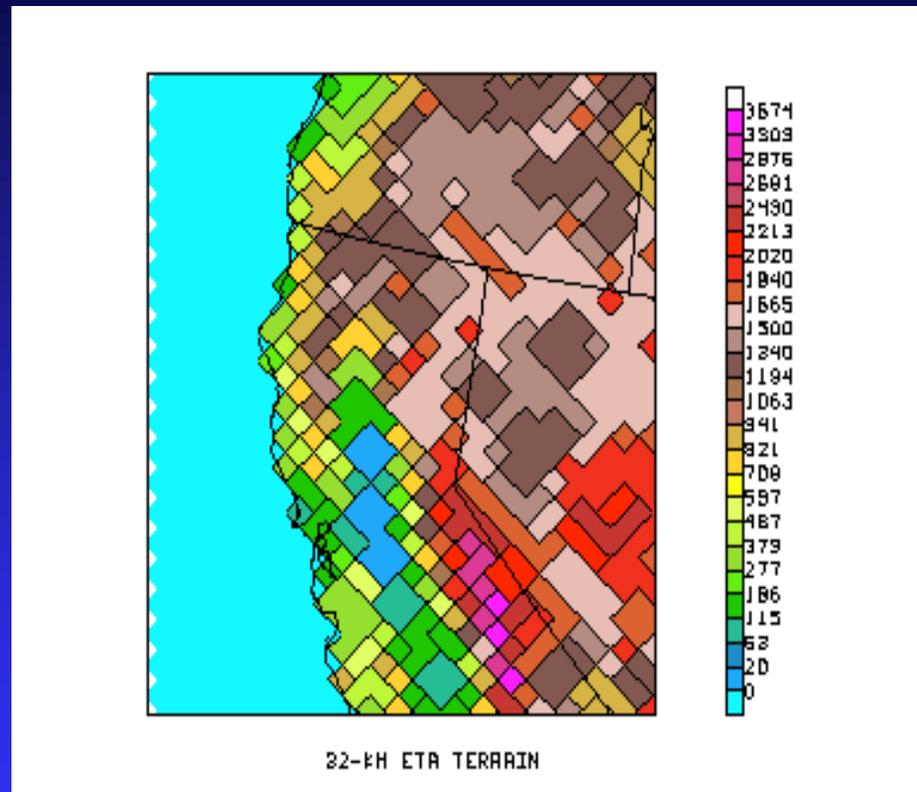
12-36 H NGM V.T. 12Z 3 JAN 97



ANALYSIS V.T. 12Z 3 JAN 97

NOTE THAT THE ETA MAX IN CA IS A LITTLE TOO FAR WEST, IT ALSO OFTEN UNDERPREDICTS PRECIPITATION OVER THE SISKIYOU MOUNTAINS OF NORTHERN CALIFORNIA.

ETA MODEL TERRAIN OVER NORTHERN CA.



BECAUSE OF ITS RESOLUTION AND THE RATHER SIMPLE MICROPHYSICS, THE ETA PREDICTS ITS PRECIPITATION MAXIMUM ASSOCIATED WITH THE SIERRA AND CASCADE RANGES TOO FAR WEST. IT DOES NOT PREDICT ENOUGH PRECIPITATION ON THE PEAKS OR ON THE DOWNWIND SIDE OF THE PEAKS.

MORE ON ETA PERFORMANCE

- TOO WET IN FLORIDA
- SOMETIMES OVERDEVELOPS LOW-LEVEL JET
- VORTICITY CENTERS IN SUMMER OFTEN ARE TOO STRONG, ESPECIALLY LATE IN FORECAST CYCLE WHEN THE FLOW IS WEAK
- OVERFORECASTS THE STRENGTH OF ANTICYCLONES

ETA AND STORM TRACKS



TENDS TO BE A LITTLE TOO FAR SOUTH WITH
LOWS AS THEY REFORM EAST OF ROCKIES.

— BY CONTRAST, NGM AND AVN
— ARE OFTEN TOO FAR NORTH

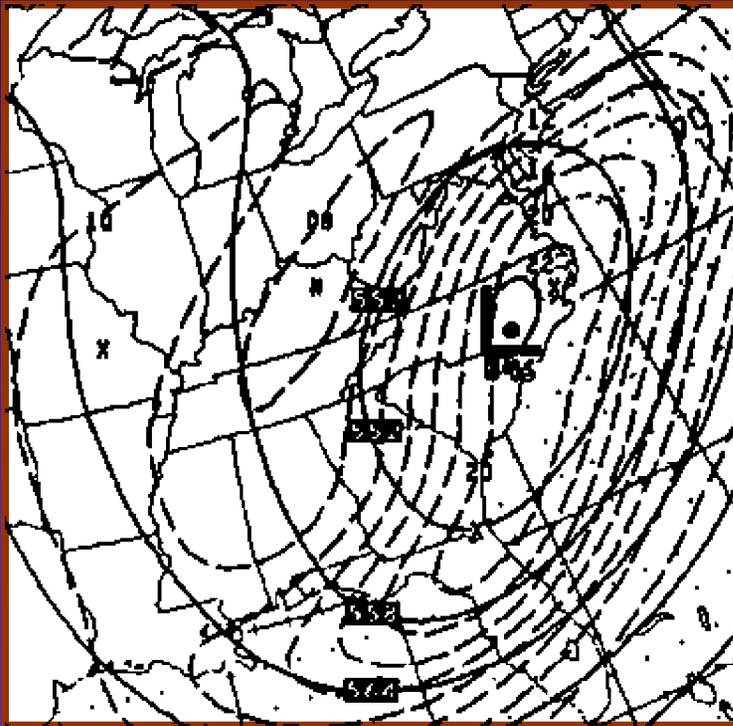


TENDS TO SOMETIMES TRACK LOWS TOO FAR
WEST ALONG THE EAST COAST.

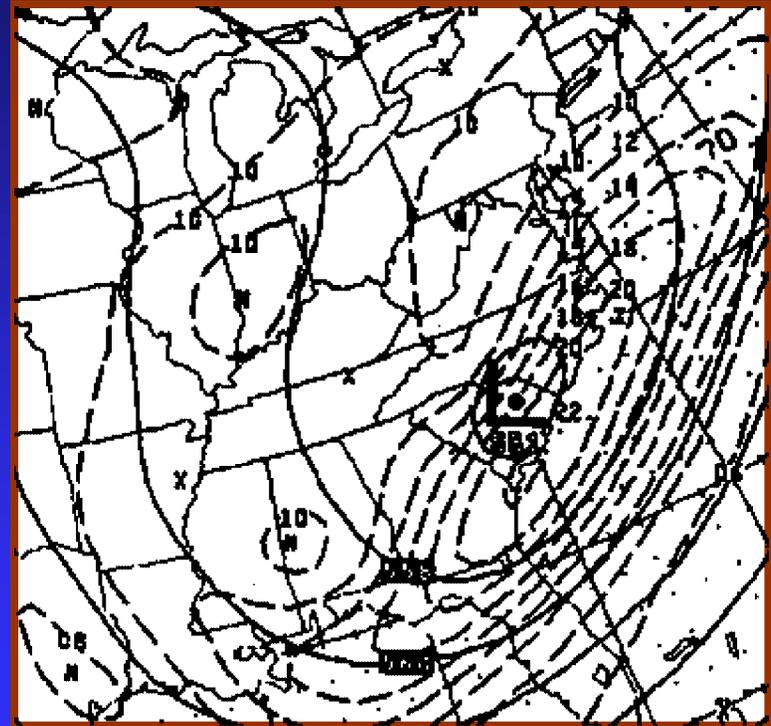
— ESPECIALLY DURING MAJOR
CYCLOGENESIS WHEN COASTAL
TROUGH IS PRESENT

COMMON ETA ERROR ALONG EAST COAST

WHEN A CLOSED UPPER LOW APPROACHES THE COAST THE ETA SOMETIMES HAS PROBLEMS FORECASTING THE LOCATION OF THE SURFACE LOW. NOTE WHERE THE UPPER LOW IS CENTERED AND WHERE THE STRONGEST UPPER-LEVEL DIVERGENCE IS IMPLIED.



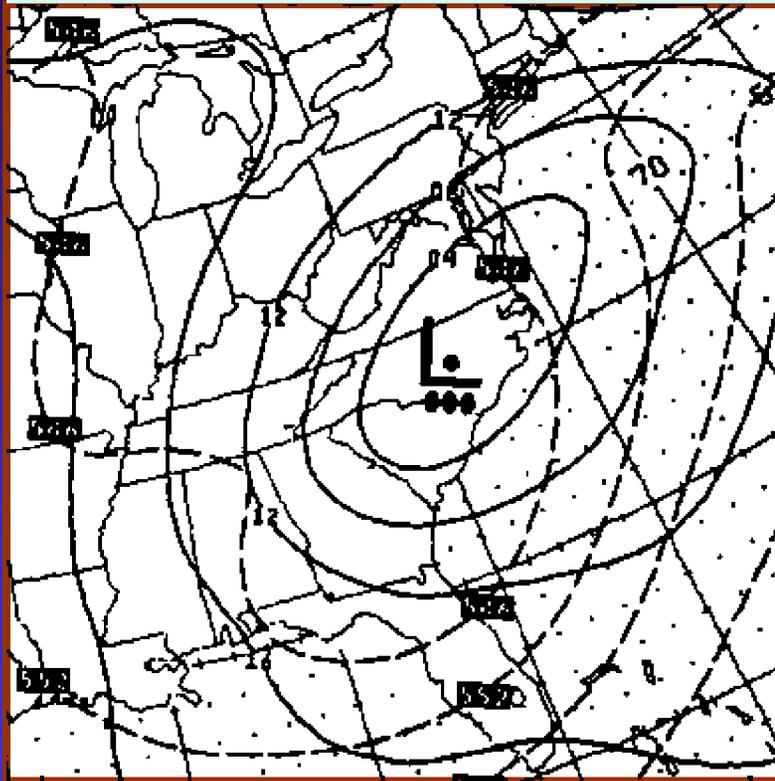
48 H ETA 500H V.T. 12Z 23 APR 98



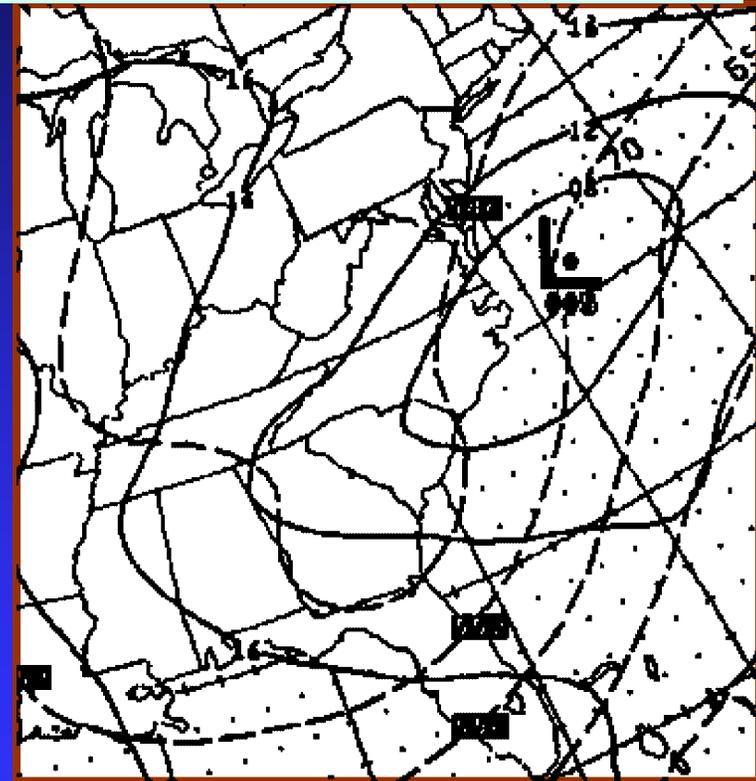
48 H NGM 500H V.T. 12Z 23 APR 98

NOTE THAT THE ETA SURFACE LOW IS A LITTLE WEST OF ITS 500 MB CENTER. THE NGM HAS A MUCH BETTER FIT TO THE 500 MB PATTERN.

THE STRONG EASTERLY COMPONENT TO THE WINDS NORTH OF THE MODEL LOW ALLOWS IT TO WRAP MOISTURE AND PRECIPITATION TOO FAR WEST



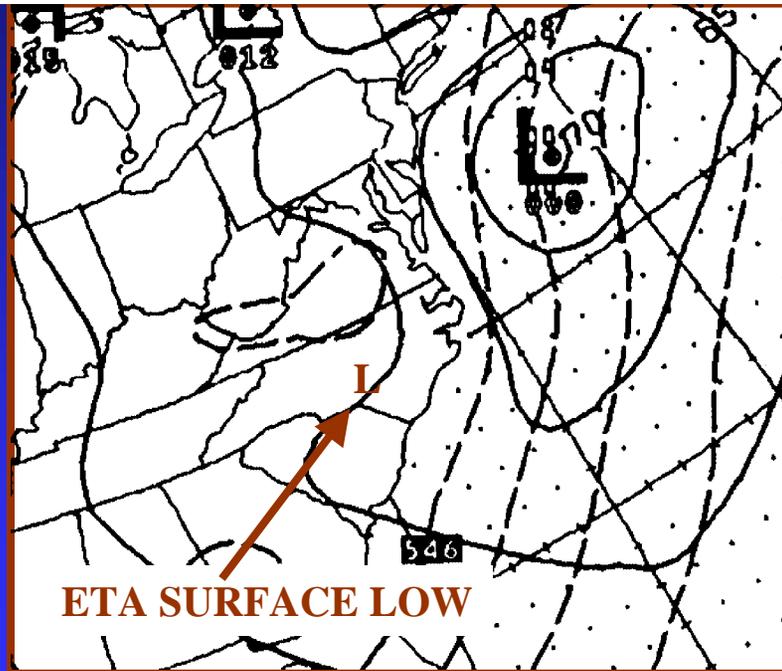
48 H ETA SURFACE V.T. 12Z 23 APR 98



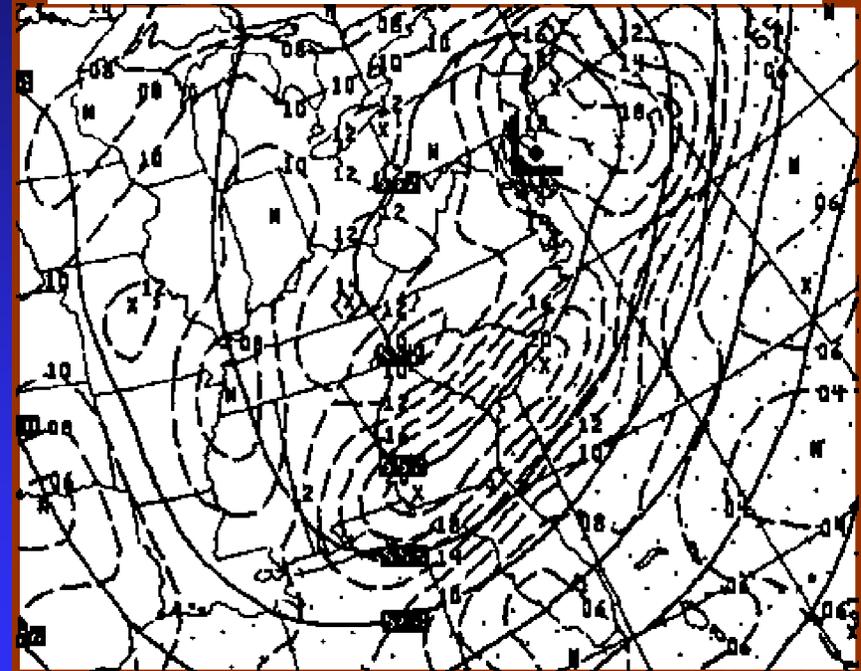
48 H NGM SURFACE V.T. 12Z 23 APR 98

THE LOW VARIES A LITTLE NORTH AND EAST OF THE NGM. REMEMBER, THE NGM IS TYPICALLY TOO SLOW WITH LOWS ALONG THE COAST.

VERIFYING SURFACE V.T. 12Z 23 APR 98



VERIFYING 500H V.T. 12Z 23 APR 98



VERIFYING PRECIPITATION

■ $\text{BIAS} = \text{FORECAST} / \text{OBSERVED}$

■ $\text{EQUITABLE THREAT} = (H - E) / (F + O - H - E)$

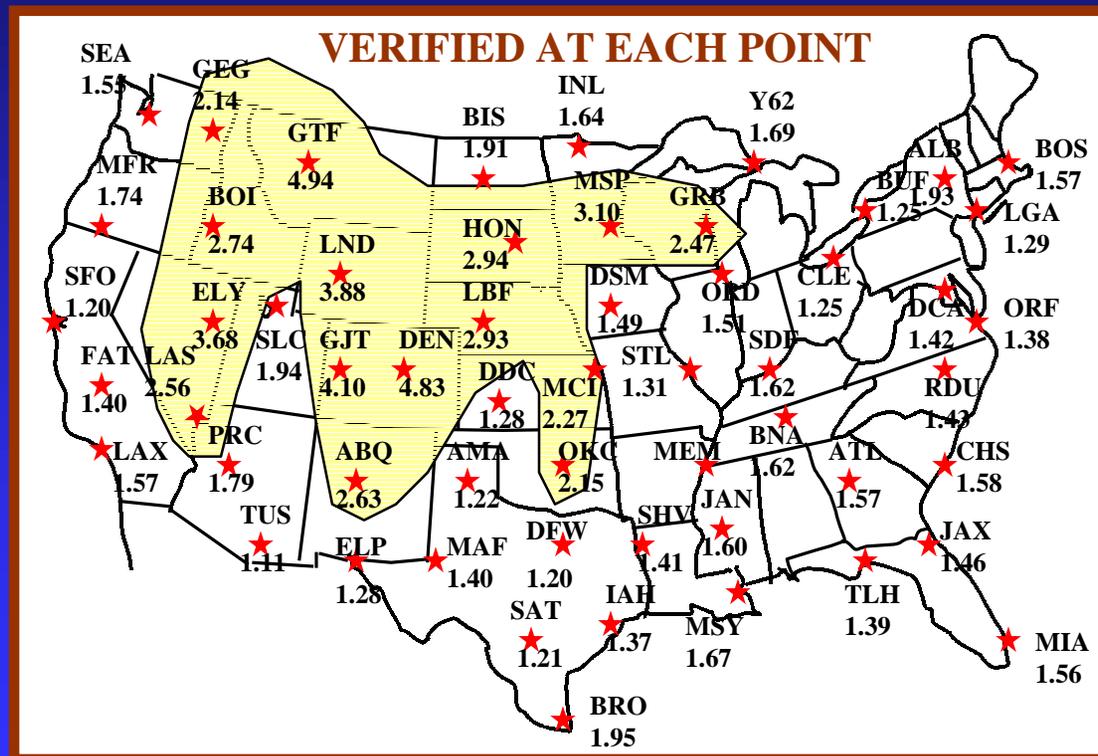
■ $\text{THREAT SCORE} = H / (F + O - H)$

- ◆ $N = \text{NUMBER OF HITS}$, $F = \text{NUMBER OF GRID POINTS FORECAST}$,
 $O = \text{GRID POINTS OBSERVED}$, $E = (F * O) / N$

MODEL BIAS AND THREAT SCORE

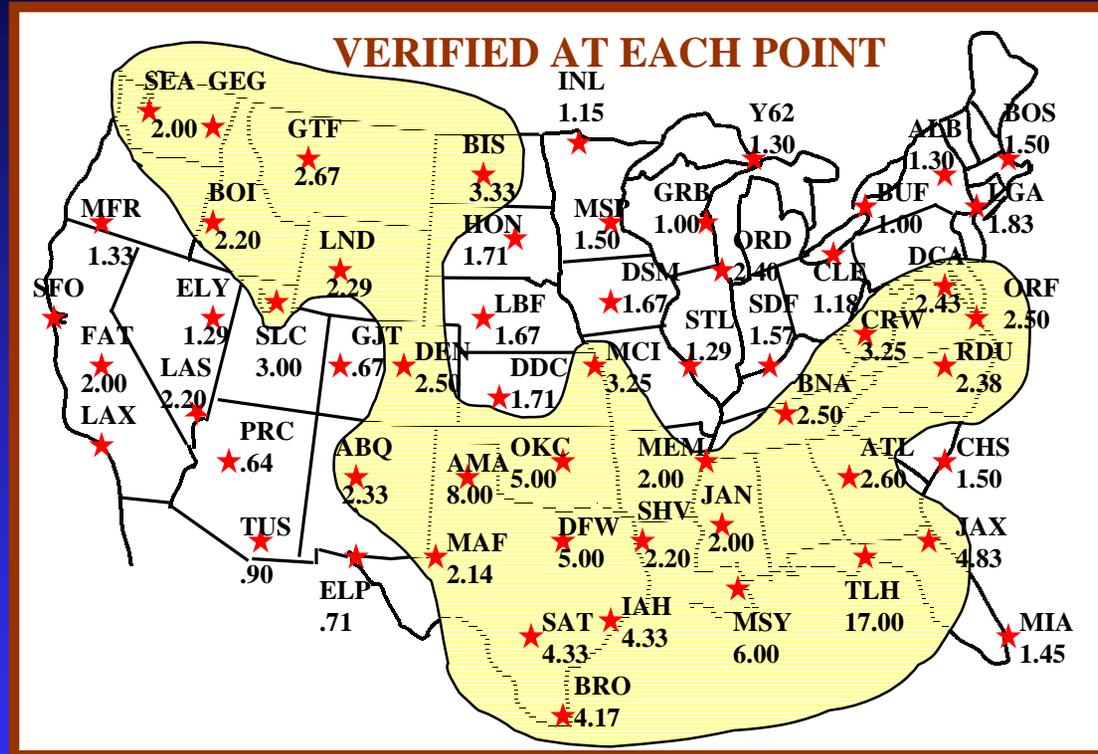
- IS DEPENDENT ON RESOLUTION OF MODEL
- HOW THE MODEL IS DISPLAYED. THE FAX VERSION OF ETA IS NOT DISPLAYED WITH FULL MODEL RESOLUTION!
- HOW THE MODEL IS VERIFIED
 - ◆ WHETHER VERIFIED AT A POINT, OR AVERAGED OVER A GRID BOX

Eta 24-36 Hr Observed Bias Dec 97-Feb. 98



FOR .01" OR MORE

Eta Has A High Bias Across The South During The Warm Season

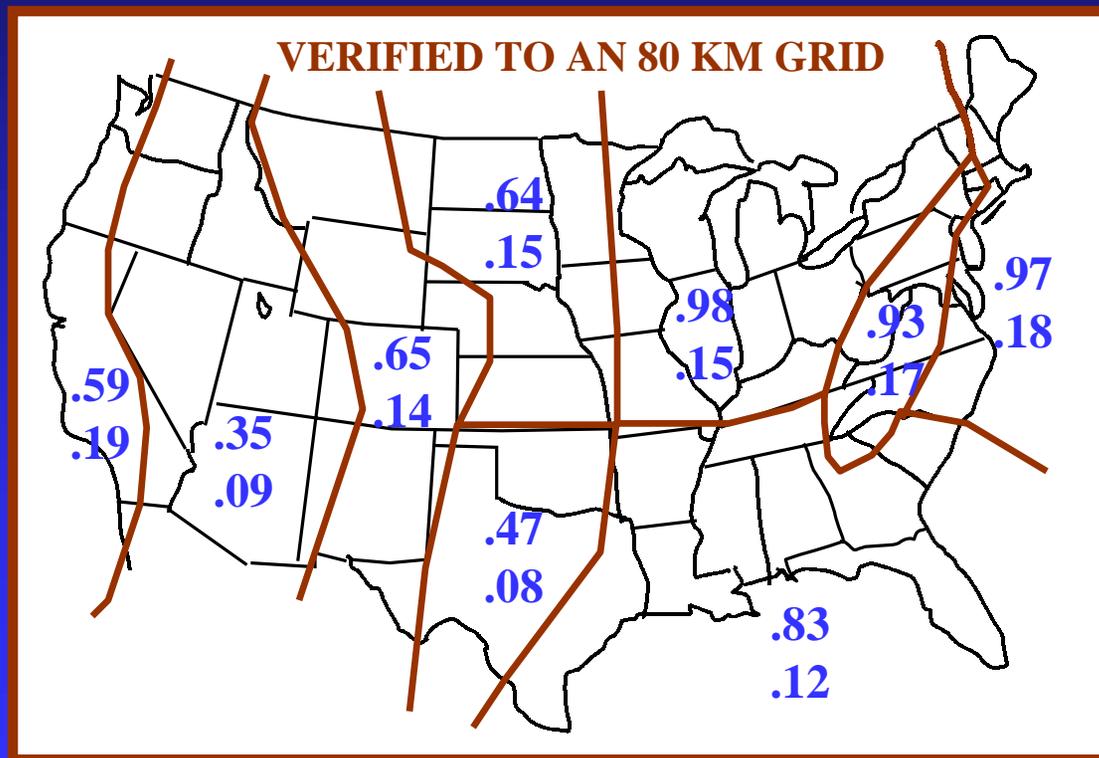


12/24 HR ETA BIAS FOR SEPT 97

NOTE THE PATTERN SIMILARITY WITH AUGUST

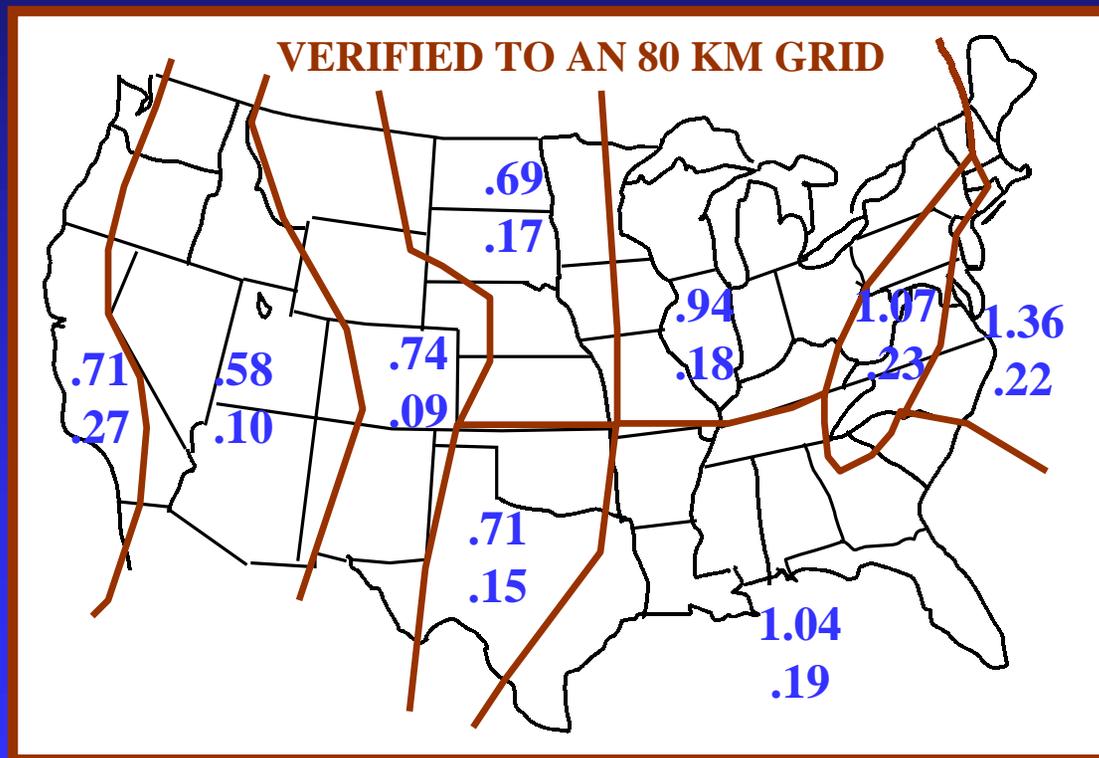
Regional ETA verification using model grid (80 km)

WARM SEASON 1.00" OR MORE VERIFICATION



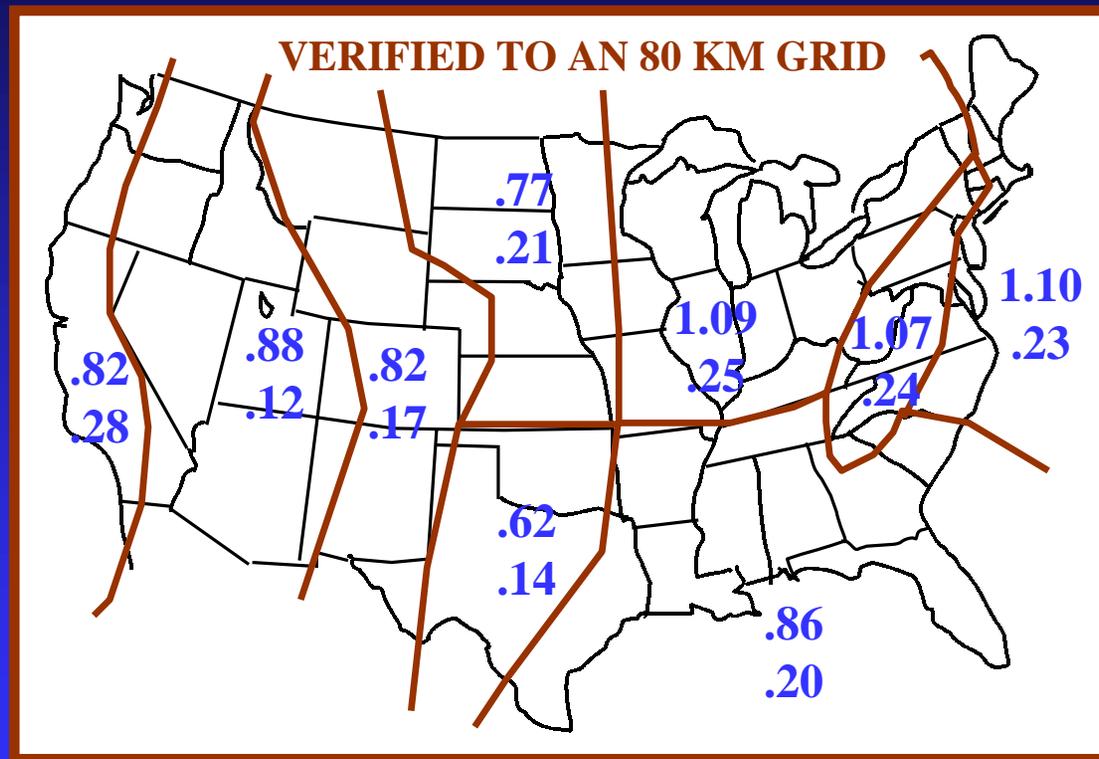
Regional ETA verification using model grid (80 km)

COLD SEASON 1.00" OR MORE VERIFICATION



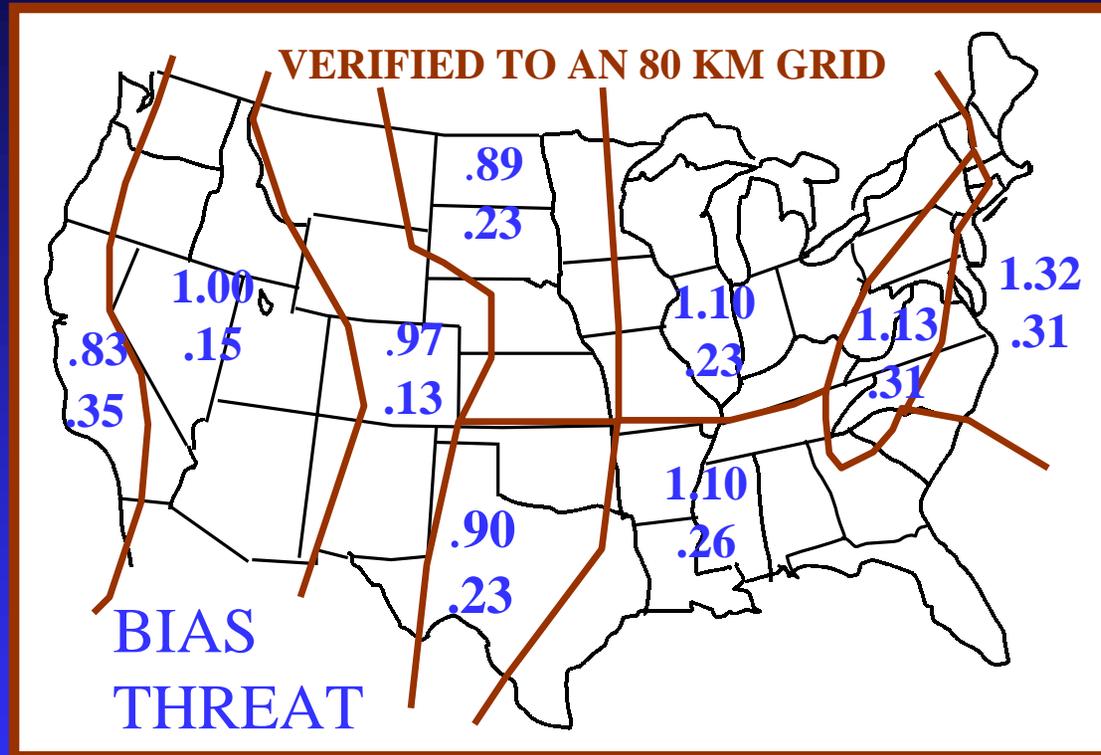
AGAIN NOTE HIGH BIAS ALONG EAST COAST
AND LOW BIAS OVER WEST

ETA .50" OR MORE PERFORMANCE DURING WARM SEASON



DURING SUMMER ETA UNDERPREDICTS
.50" OR GREATER AMOUNTS IN PLAINS.
MESO-ETA HAS SAME BIAS

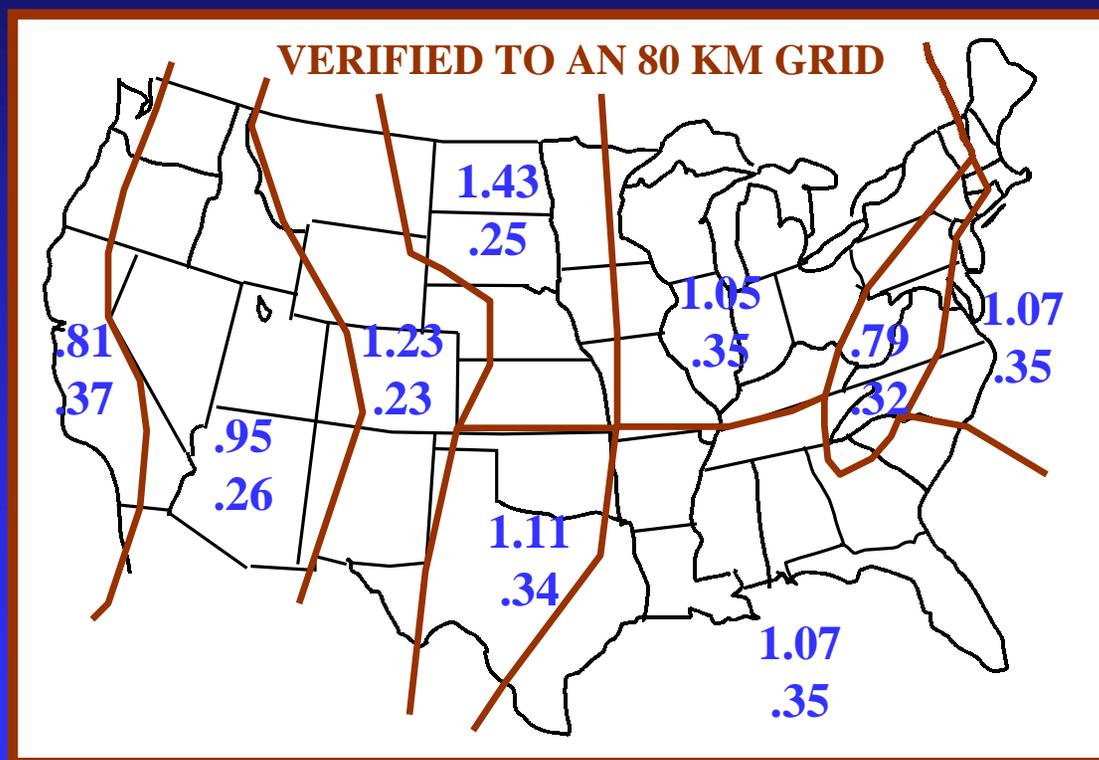
ETA PERFORMANCE FOR .50 OR GREATER AMOUNTS APR 96-NOV 97



ETA OVERPREDICTS .50 OR GREATER ACROSS SOUTH AND ALONG EAST COAST. MESO-ETA HAS SAME BIAS

Regional ETA verification using model grid (80 km)

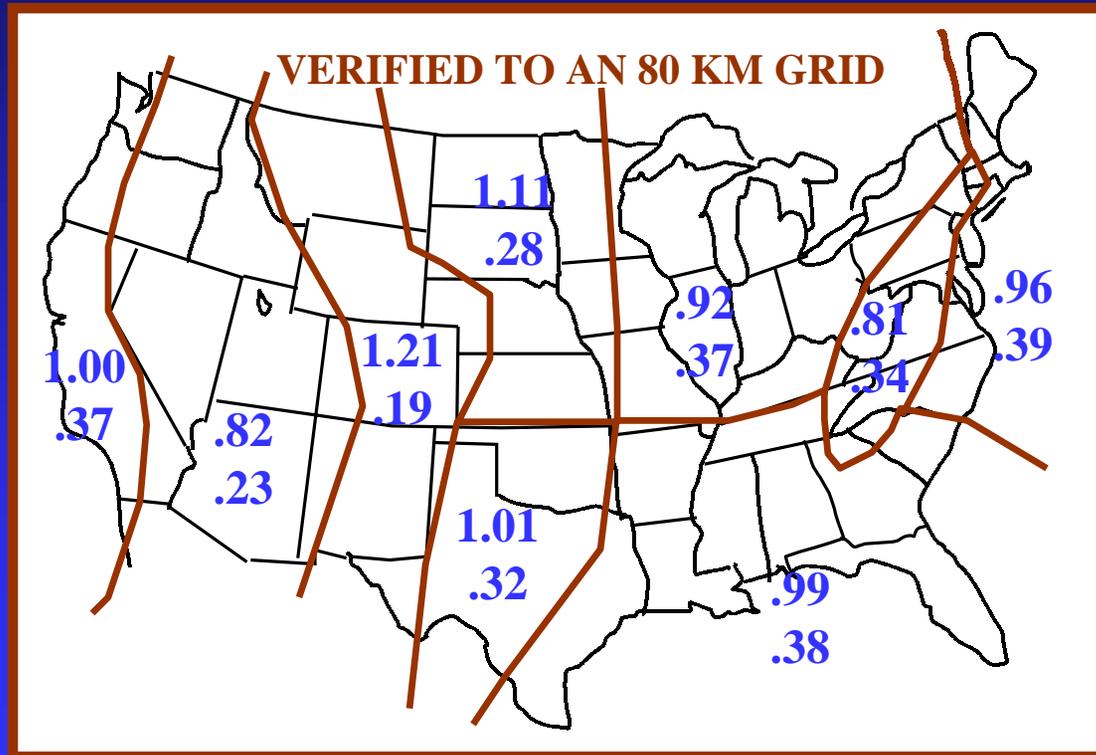
.01" OR GREATER AMOUNTS DURING COLD SEASON



HIGHEST THREATS ALONG WEST COAST.
HIGH BIAS OVER UPSLOPE AREAS EAST
OF ROCKIES AND OVER PLAINS

Regional ETA verification using model grid (80 km)

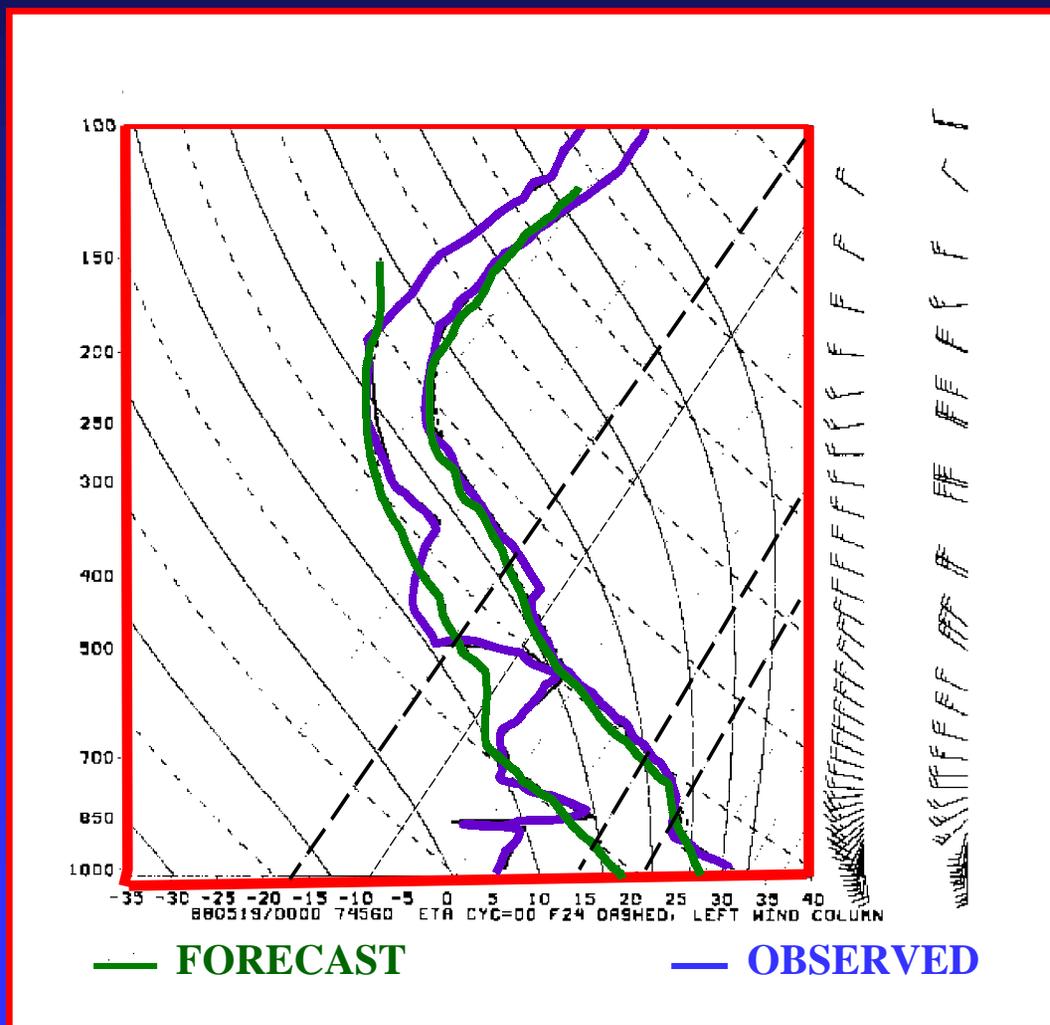
.01" OR GREATER AMOUNTS DURING WARM SEASON



BIG DIFFERENCES WITH POINT VERIFICATION. USING A POINT VERIFICATION, YOU SEE THE HUGE BIASES OVER THE SOUTH

ETA MODEL HAS PROBLEMS PREDICTING THE STABILITY.

HIGH SOIL MOISTURE CASE



WHEN SOIL MOISTURE IS HIGH, THE ETA DEWPOINTS ARE TOO HIGH AND LOW-LEVEL TEMPERATURES ARE TOO LOW.

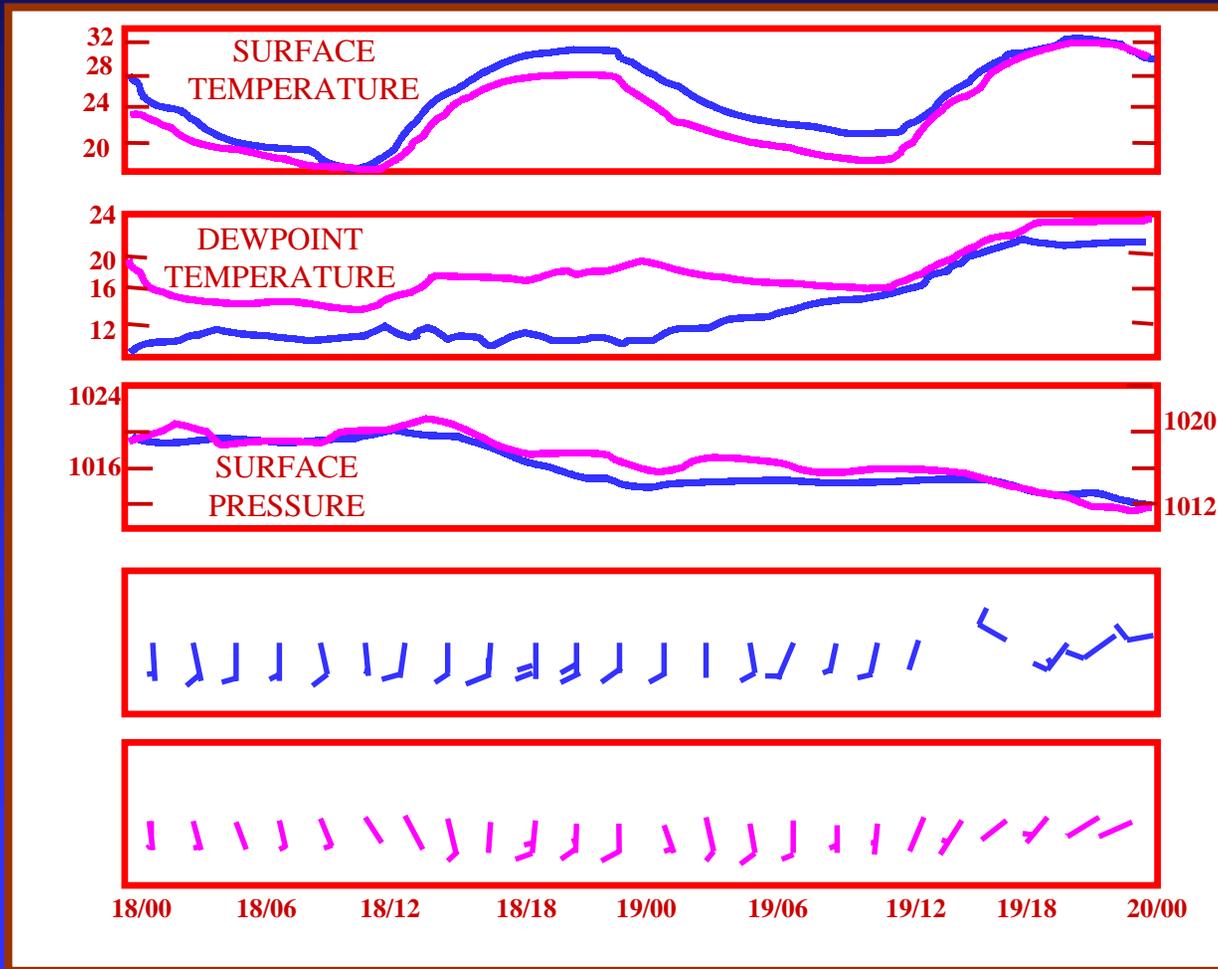
THE ETA FORECAST
CAPE=1177, LI=-4

OBSERVED
CAPE=5, LI=2

THIS SOMETIMES
CAUSES THE MODEL TO
BE TOO UNSTABLE

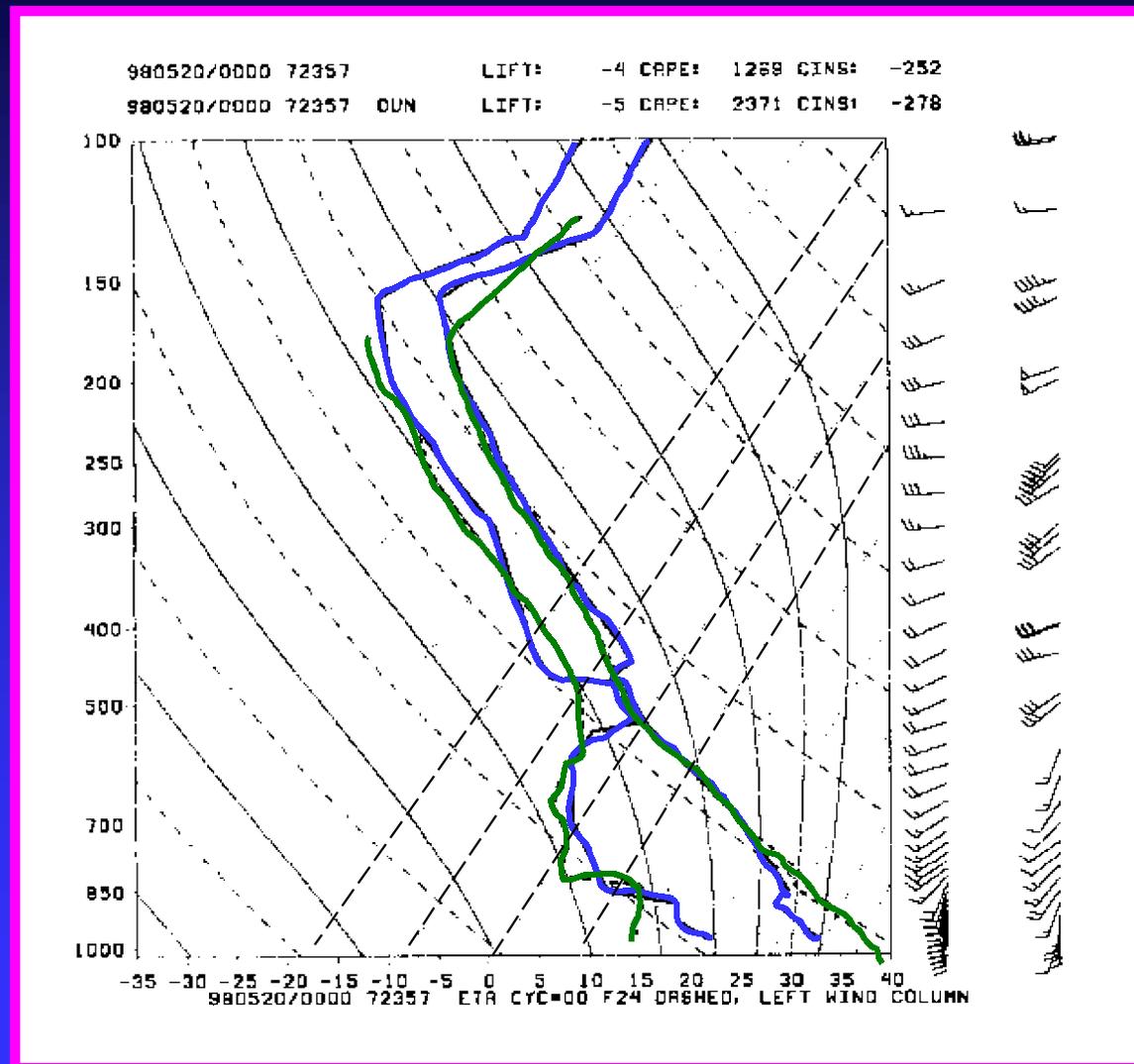
WHEN HIGH SOIL MOISTURE IS PRESENT, OR WHEN THE MODEL FIRST GUESS THINKS THE SOIL MOISTURE IS HIGH,

THEN, THE MODEL FORECAST SURFACE DEWPOINTS ARE TOO HIGH AND SURFACE TEMPS ARE TOO LOW.

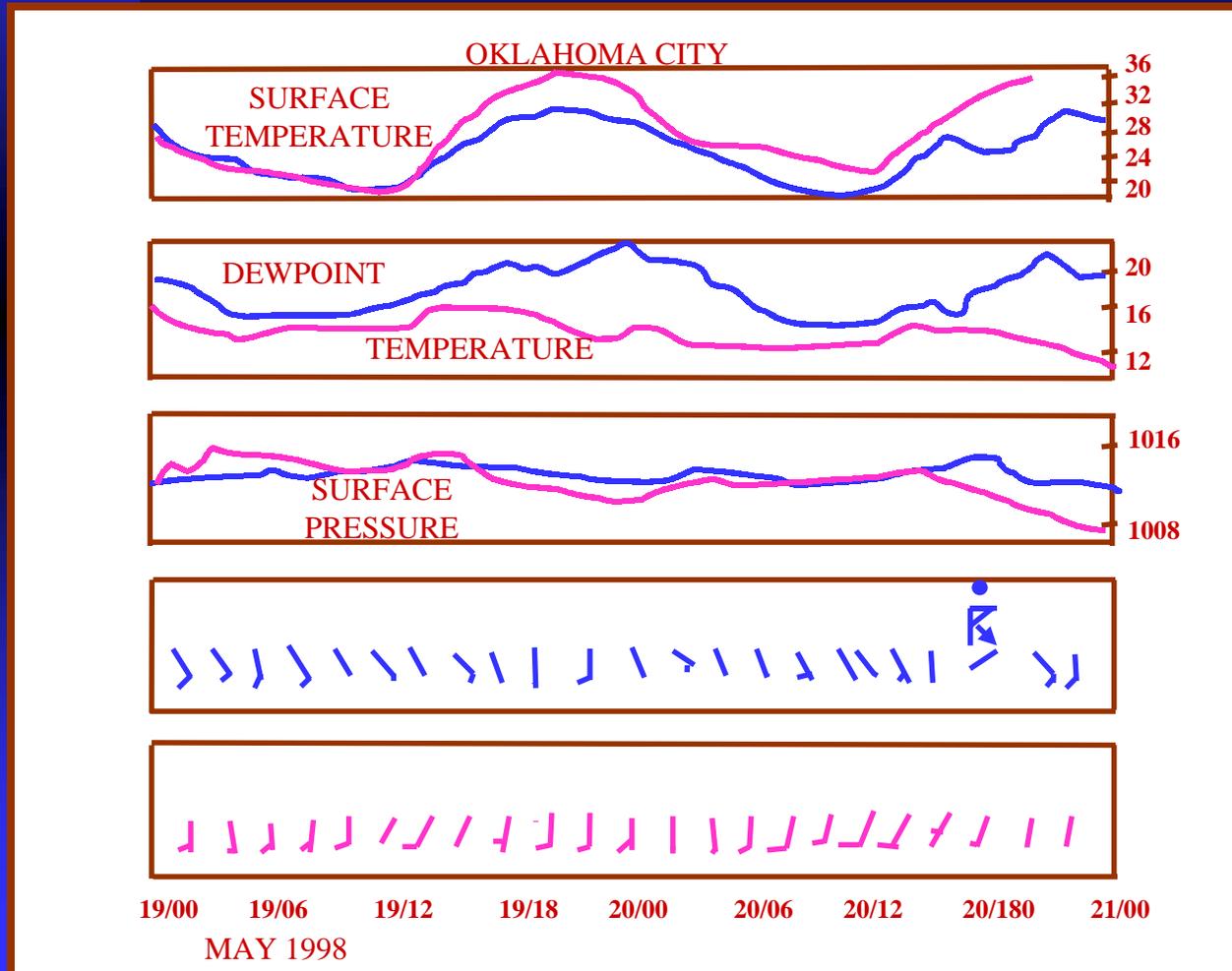


THE MODEL UNDERPREDICTS THE BOUNDARY LAYER WINDS. HOWEVER, MODEL FORECAST 850 MB WINDS ARE OFTEN TOO STRONG

WHEN LOW SOIL MOISURE IS PRESENT DURING SUMMER OVER THE HIGH PLAINS, ESPECIALLY WEST TX, THE FORECAST CAPE IS TOO LOW

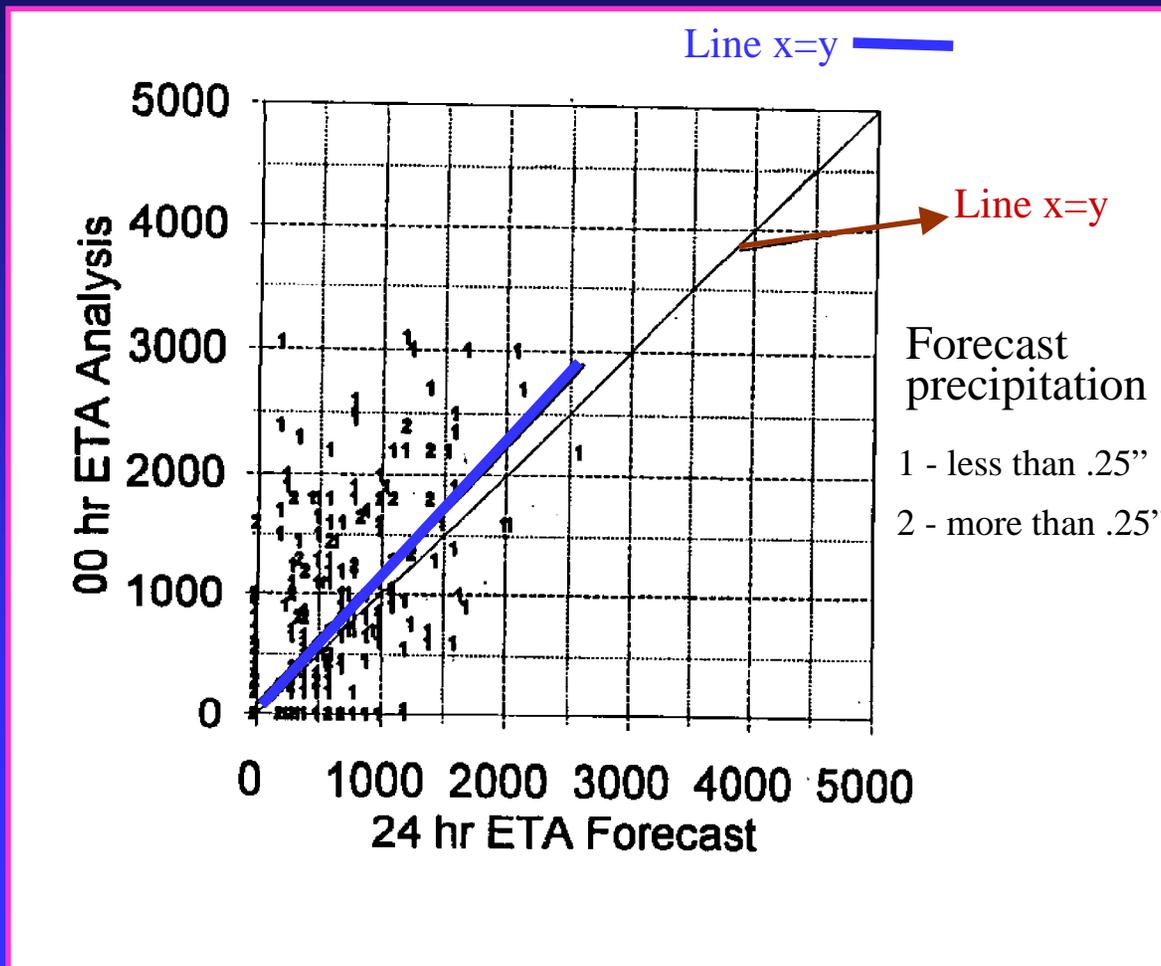


WHEN SO MOISTURE IS LOW IN SUMMER IN THE PLAINS, THE SURFACE DEWPOINT IS TOO LOW AND THE TEMPERATURE IS TOO HIGH



ETA SURFACE WINDS WERE TOO WESTERLY, WAS THERE TOO MUCH DOWNSLOPING?

Forecast vs. Observed Best Cape Spring 96



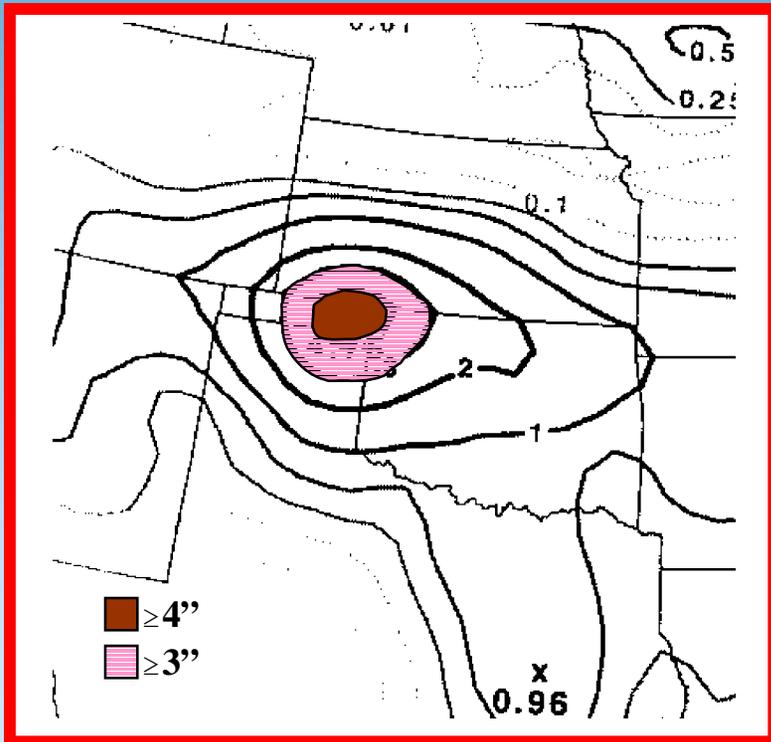
Note the large spread.
The model stability
forecasts are worst
when precipitation is
forecast

A NUMBER OF AVN/MRF PERFORMANCE CHARACTERISTICS HAVE CHANGED IN THE PAST YEAR.

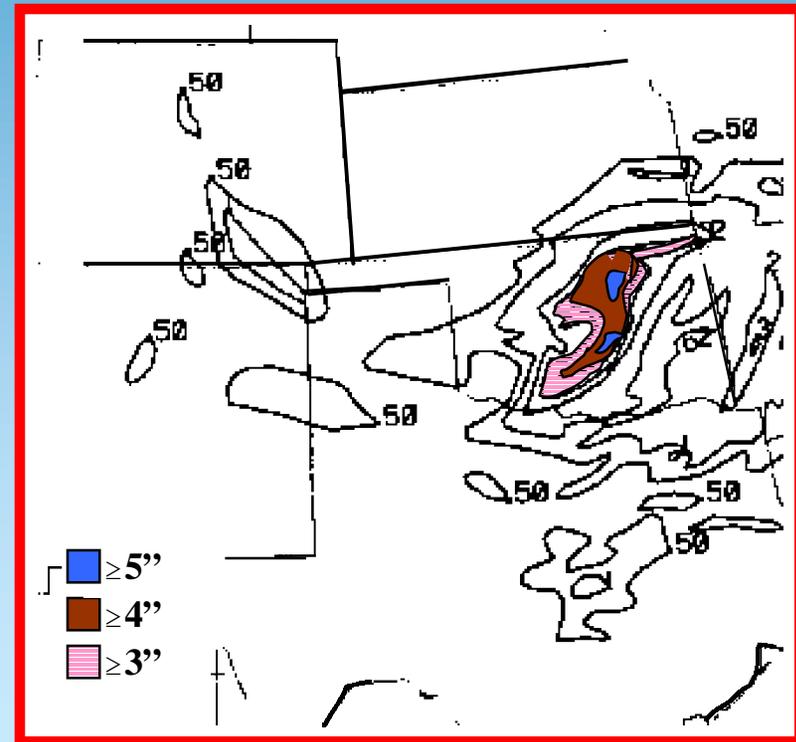
- THE AVN/MRF NO LONGER APPEAR TO UNDERPREDICT PRECIPITATION DURING THE WARM SEASON, ESPECIALLY FOR HIGHER AMOUNTS.
- THE AVN/MRF NO LONGER “OFTEN UNDERPREDICTS SURFACE LOWS, ESPECIALLY OVER OCEANS”
- TROPICAL “BLOWUPS” HAVE NOT BEEN MINIMIZED. THEY ARE STILL COMMON DURING THE WARM SEASON. THE MRFX WILL NOT STOP THE PROBLEM.

AVN/MRF Often Have Problems Handling Upslope Events

Around 75% of the precipitation predicted by the AVN during this event was grid scale, rather than convective, precipitation. In these cases, the model QPF is often too far to the northwest. The maximum rainfall falls farther to the south along the surface front.



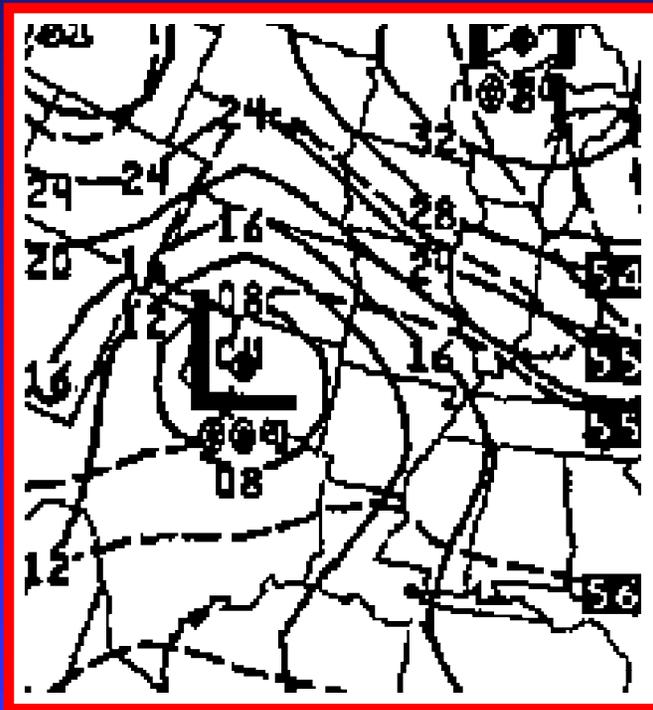
12-36 hr AVN QPF V.T. 12Z 27 APR 98



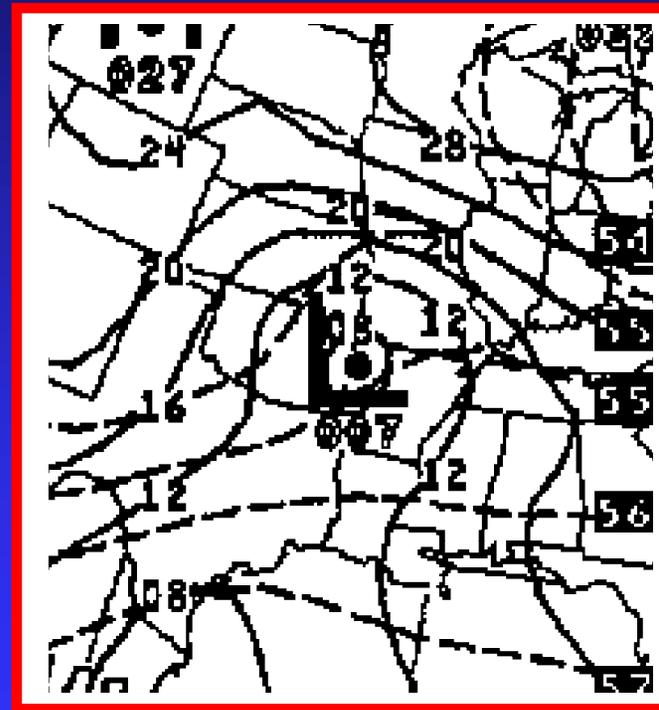
VERIFYING 24H PRECIPITATION
V.T. 12Z 27 APR 98

About 75% of the AVN Rainfall Over the OK Panhandle Was Grid-scale Precipitation (Not Convection).

The overprediction of grid-scale precipitation may result in latent heat being released at too low a level in the atmosphere. This tends to cause pressures to lower, often resulting in the lows wrapping up too far to the west or northwest.



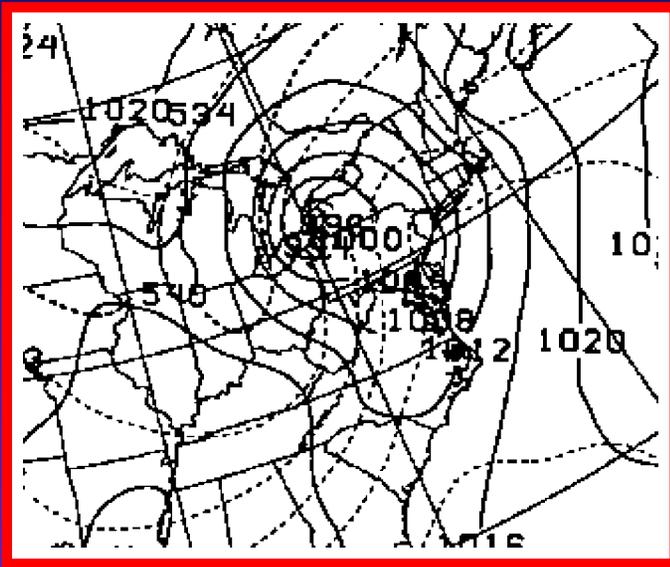
36-HR AVN/MRF
V.T. 12Z 27 APRIL 98



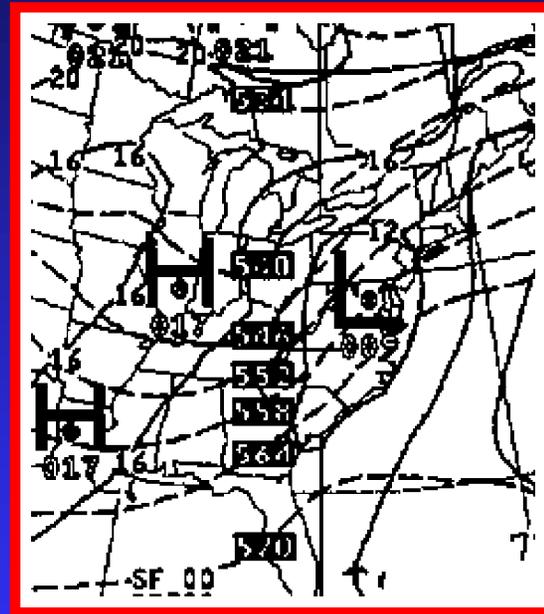
VERIFYING AVN/MRF
V.T. 12Z 27 APRIL 98

Another Case: AVN Wraps Low Too Far North And West. Both Surface and 500 mb Lows Are Too Deep.

PRECIPITATION FORECAST IS POOR BECAUSE OF BAD SURFACE AND 500 MB FORECASTS OR VICE-VERSA.



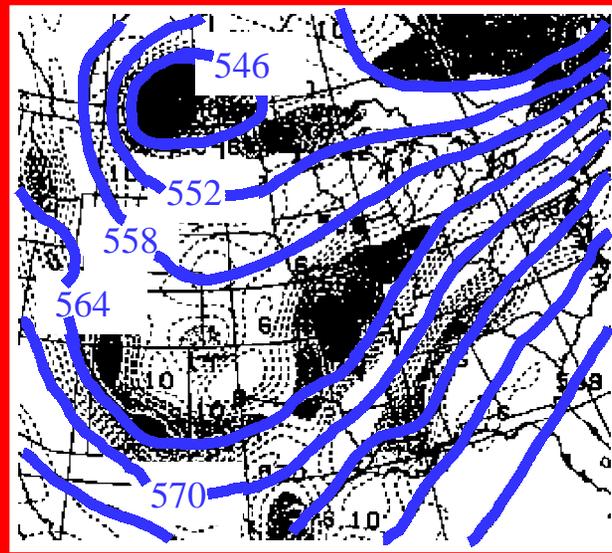
AVN 36 HR V.T. 00Z
APR 1998



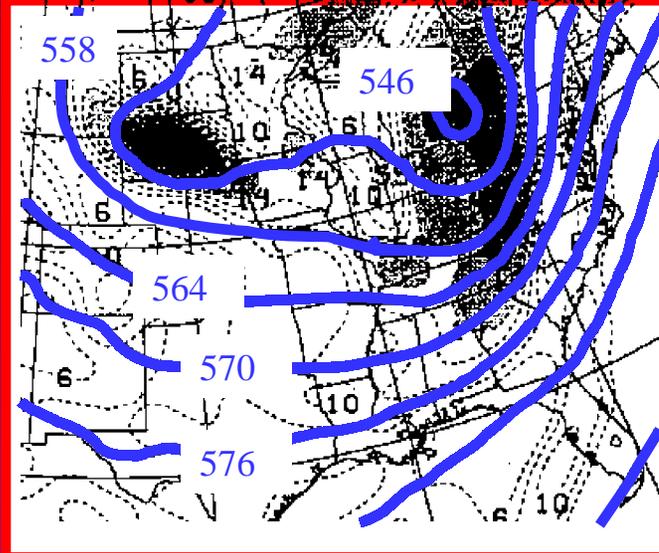
AVN VERIFYING
SURFACE ANALYSIS
V.T. 00Z APR 1998

Is this another case with some type of latent heating feedback problem?

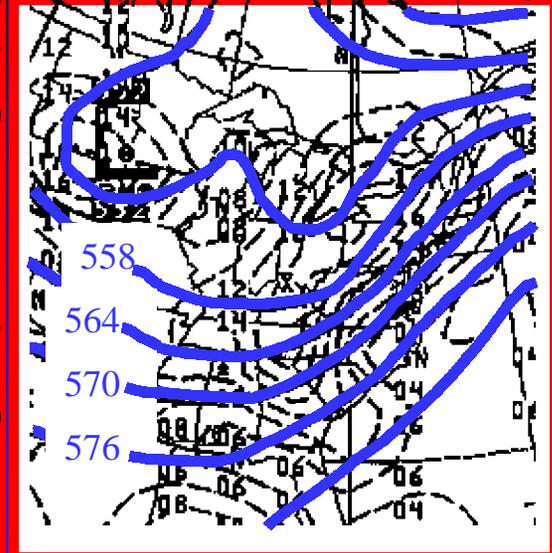
Aviation Model handling of 500 mb trough



06h V.T. 18Z Apr 18



36h V.T. 00Z Apr 20

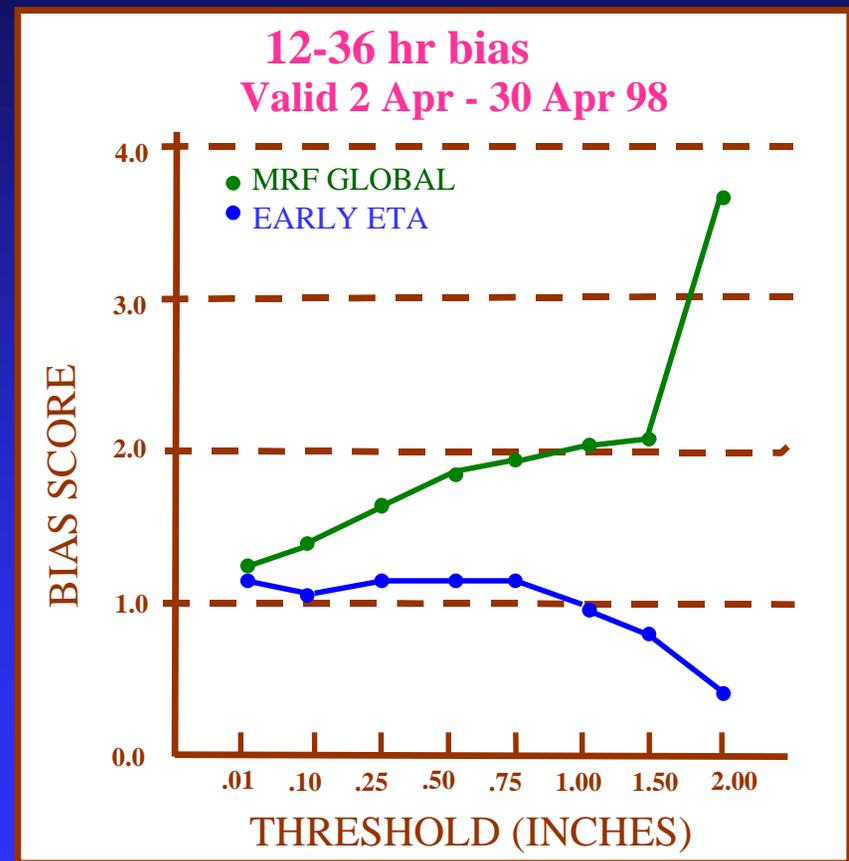
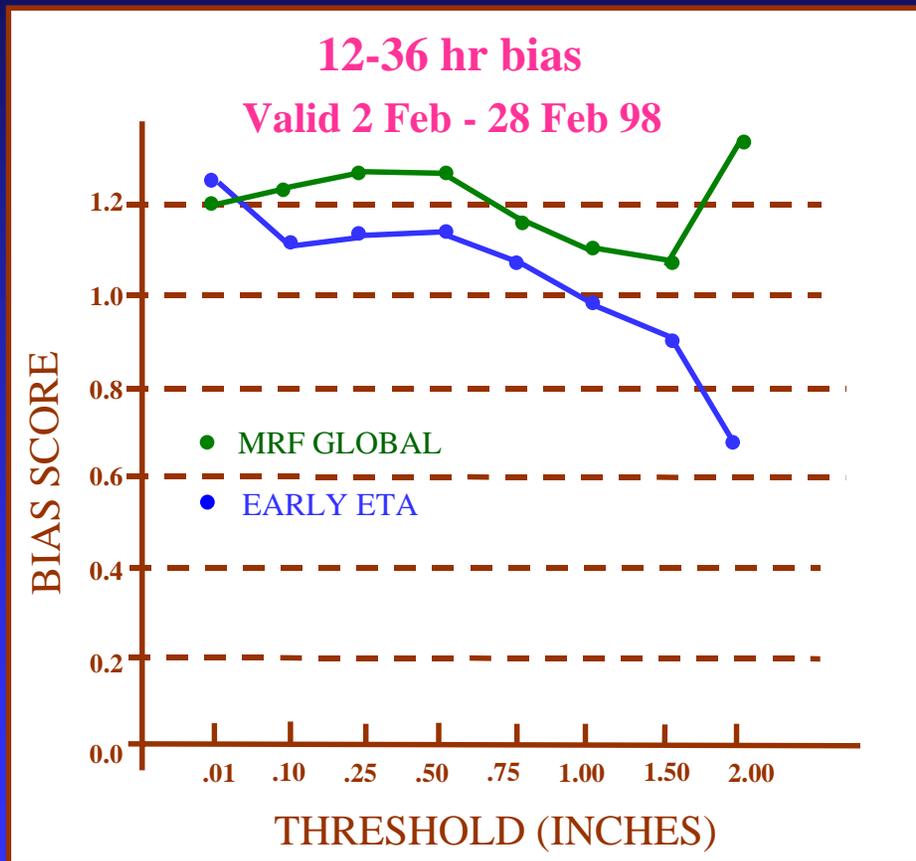


Analysis V.T. 00Z
Apr 20

The vorticity increases as the system lifts northeastward even though it never taps into or phases with any northern stream energy.

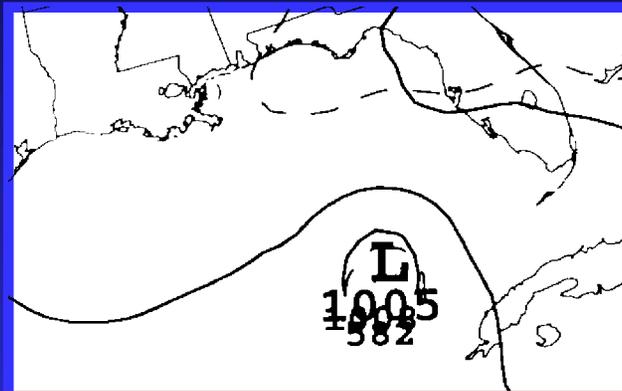
BIAS COMPARISON OF 12-36 HR MRF AND EARLY ETA FORECASTS

VERIFIED TO AN 80 KM GRID

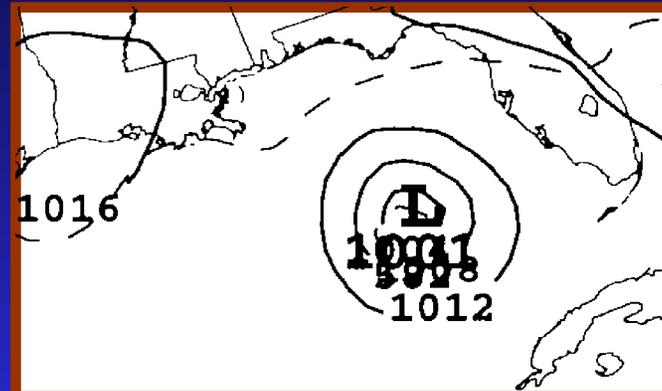


THE MRF AND AVN OVERPREDICT ALL THRESHOLDS ESPECIALLY THE HEAVIER ONES DURING SPRING AND SUMMER

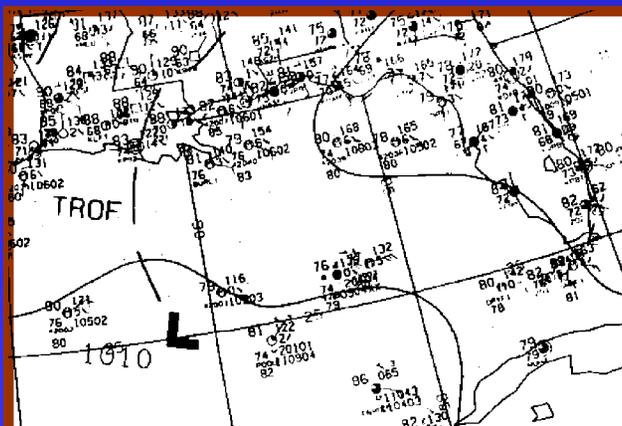
The MRF and MRFX spin-up precipitation bombs and tropical systems erroneously at all time ranges.



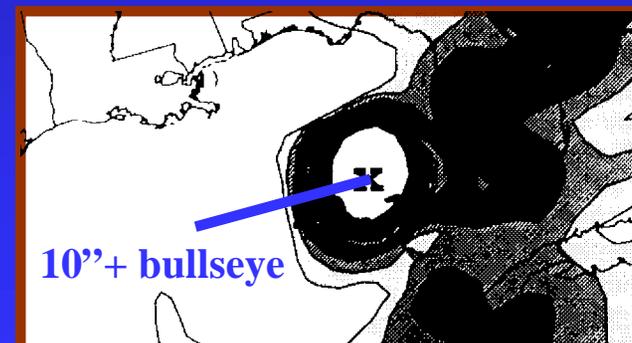
24-h MRFX v.t. 12Z 27 May 1998



36-h MRFX v.t. 00Z 28 May 1998



SFC ANALYSIS v.t. 00Z 28 May 1998



24-36-h MRFX v.t. 00Z 28 May 1998

MRF PERFORMANCE FOR 3-5 DAY FORECASTS

- SHALLOW COLD AIR IS NOT HANDLED WELL. THE MODEL IS SLOW TO TRANSPORT SHALLOW COLD AIRMASSSES, ESPECIALLY ARCTIC AIRMASSSES JUST TO THE EAST OF THE ROCKY MOUNTAINS OR APPALACHIAN CHAIN.
- EASTERLY BOUNDARY LAYER WINDS ARE OFTEN OVERPREDICTED ALONG THE FRONT RANGE OF THE ROCKY MOUNTAINS.
- MODEL HAS A SLIGHT COLD BIAS, ESPECIALLY OVER THE EASTERN THIRD OF THE COUNTRY.

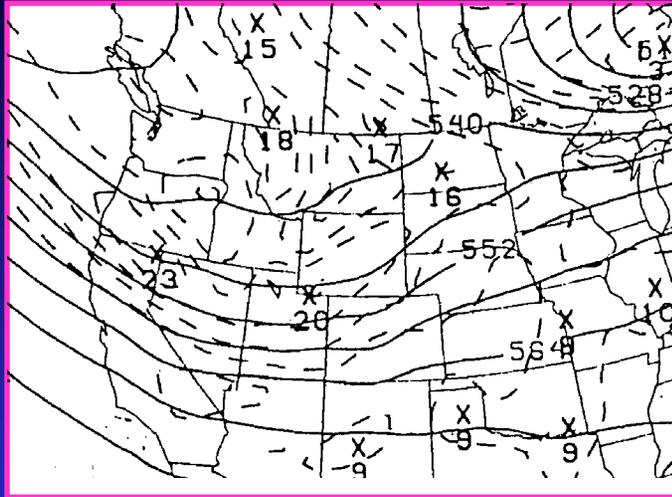
MRF PERFORMANCE (3-5 DAY) CONTINUED.

- MODEL TENDS TO PHASE SEPARATE STREAMS TOO MUCH.
- AT HIGH LATITUDES (NORTH OF 50°), THE MODEL PREDICTS TOO MUCH RETROGRESSION
- TENDS TO WEAKEN THE REMAINS OF UPPER LOWS TOO QUICKLY THAT ARE COMING OUT OF THE SOUTHWEST

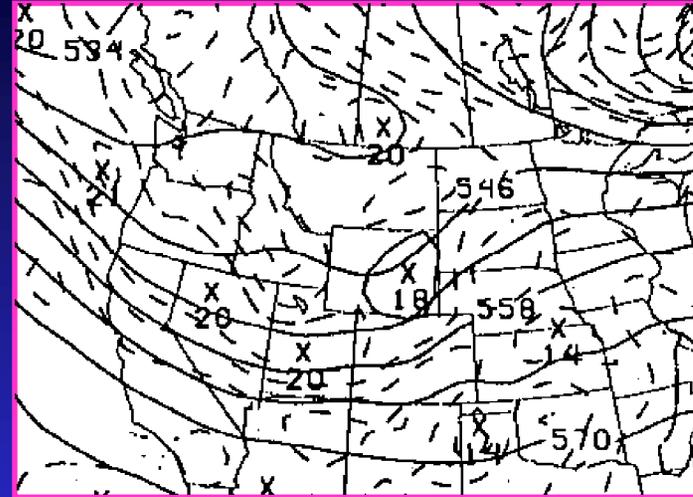
NGM AND THE SURFACE PATTERN

- OVERDEVELOPS SURFACE LOWS OVER LAND ESPECIALLY TO THE LEE OF THE ROCKIES
- UNDERDEVELOPS LOWS OVER WATER
- HAS NORTHERLY DISPLACEMENT ERROR OVER ROCKIES AND IMMEDIATELY IN THEIR LEE
- HAS BIG PROBLEMS HANDLING ARCTIC AIR MASSES (ESPECIALLY ALONG THE FRONT RANGE OF MOUNTAIN RANGES)

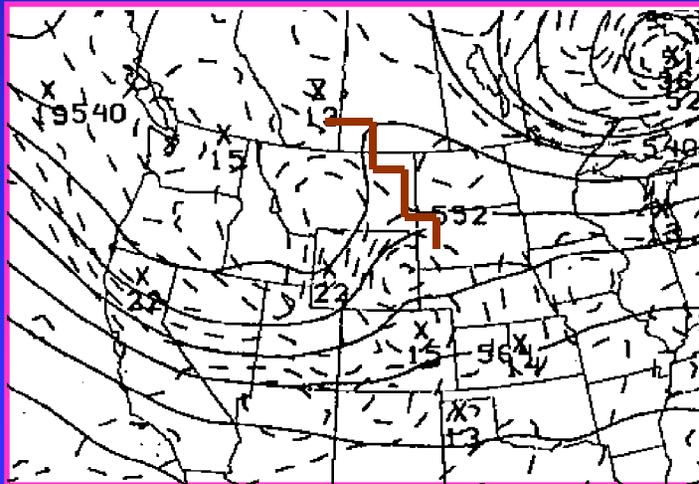
THE NGM LOWERS HEIGHTS TOO MUCH IN THE NORTHERN ROCKIES AND HIGH PLAINS



36 HR NGM V.T. 00Z APR
09, 1995



36 HR AVN V.T. 00Z APR 09,
1995



500 H ANALYSIS

NOTE HOW BOTH THE NGM AND AVN CRASH THE HEIGHTS AND PUSH THE SHORTWAVE RIDGE AXIS EASTWARD. THIS ALSO ALLOWS WARM ADVECTION TO DEVELOP TOO QUICKLY ACROSS THE NORTHERN PLAINS.

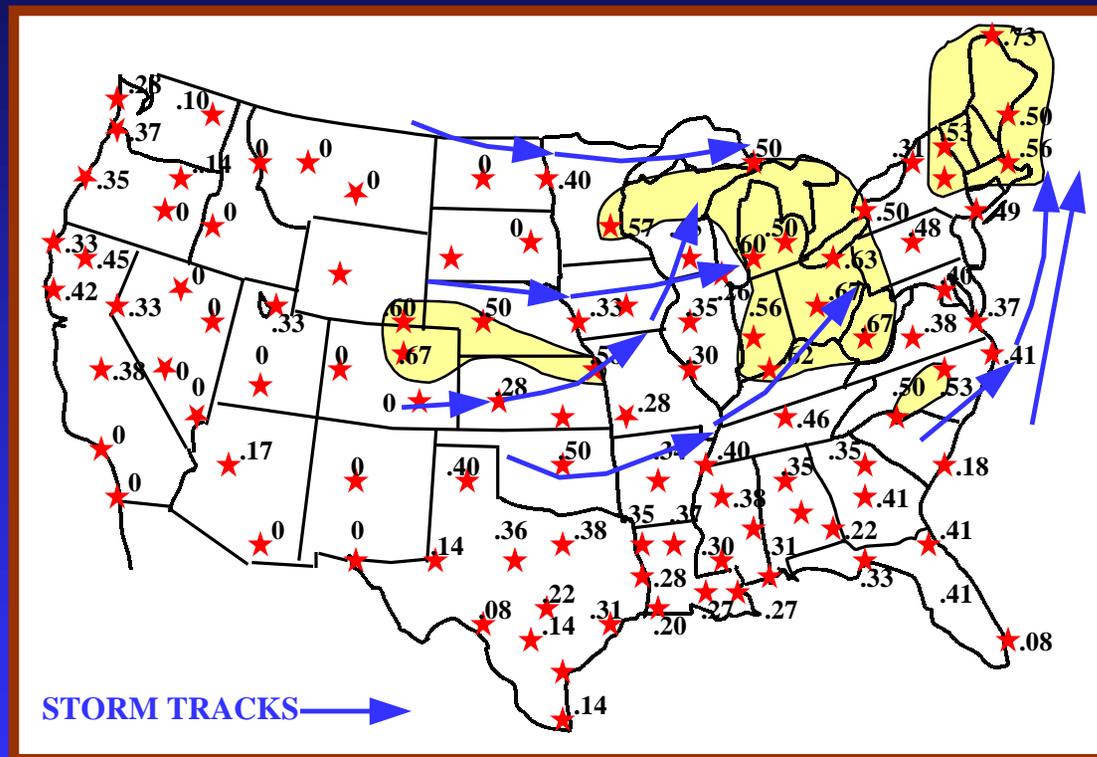
Why models have problems with arctic airmasses

- Terrain is averaged
- Initialization process sometimes robs shallow airmass of its coldness
- Models have problems handling the strength of the inversion
- The sigma coordinate system
- The leading edge of the ETA LI gradient is often the best indicator of the frontal position

LOWS TO THE LEE OF THE ROCKIES

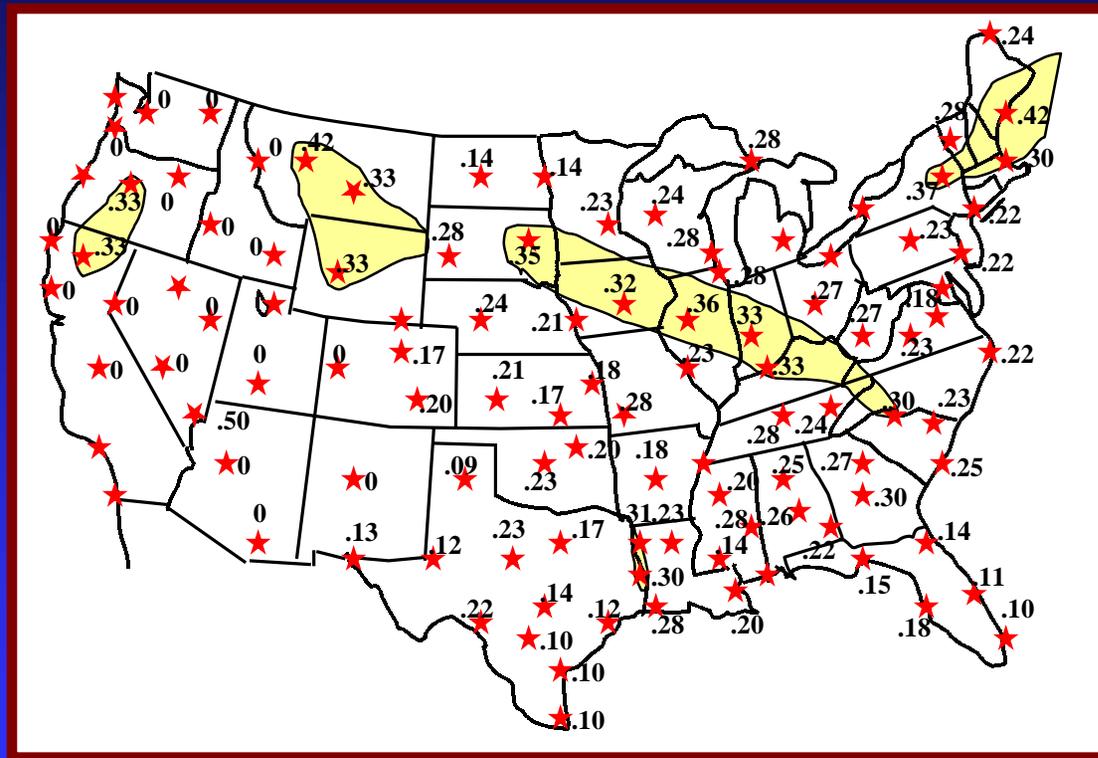
- THE AVN AND NGM USUALLY PREDICT THEM TO FORM TOO FAR NORTH
- USE THE 300 MB UPPER LEVEL JET. THE SURFACE LOW IS USUALLY FOUND IN THE LEFT EXIT REGION OF THE JET, USUALLY JUST TO THE NORTH

NGM 12-36 Hr Winter Threat Score For .50'' Or Greater Amounts



THE HIGHEST THREAT SCORES
ARE FOUND NORTH OF THE
STORM TRACK

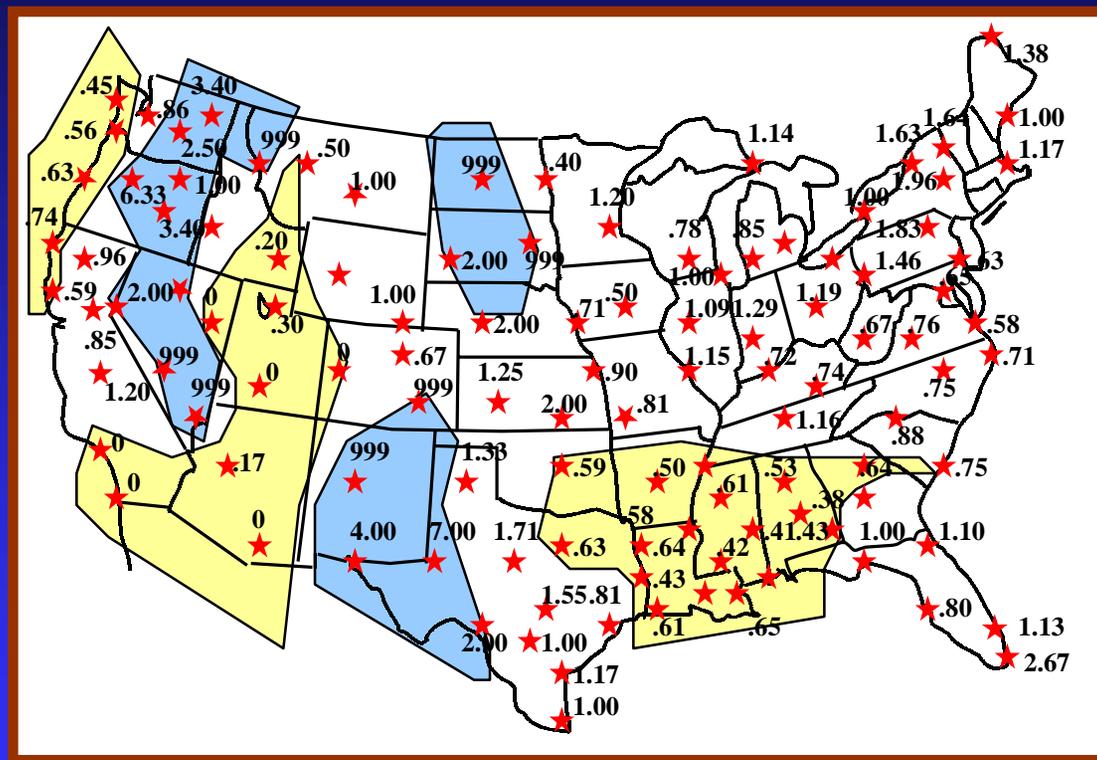
12-36 HR .50" OR GREATER NGM WARM SEASON THREAT SCORE



NOTE LACK OF SKILL IN WEST. AREAS OF HIGHER SKILL ARE SHADED YELLOW.

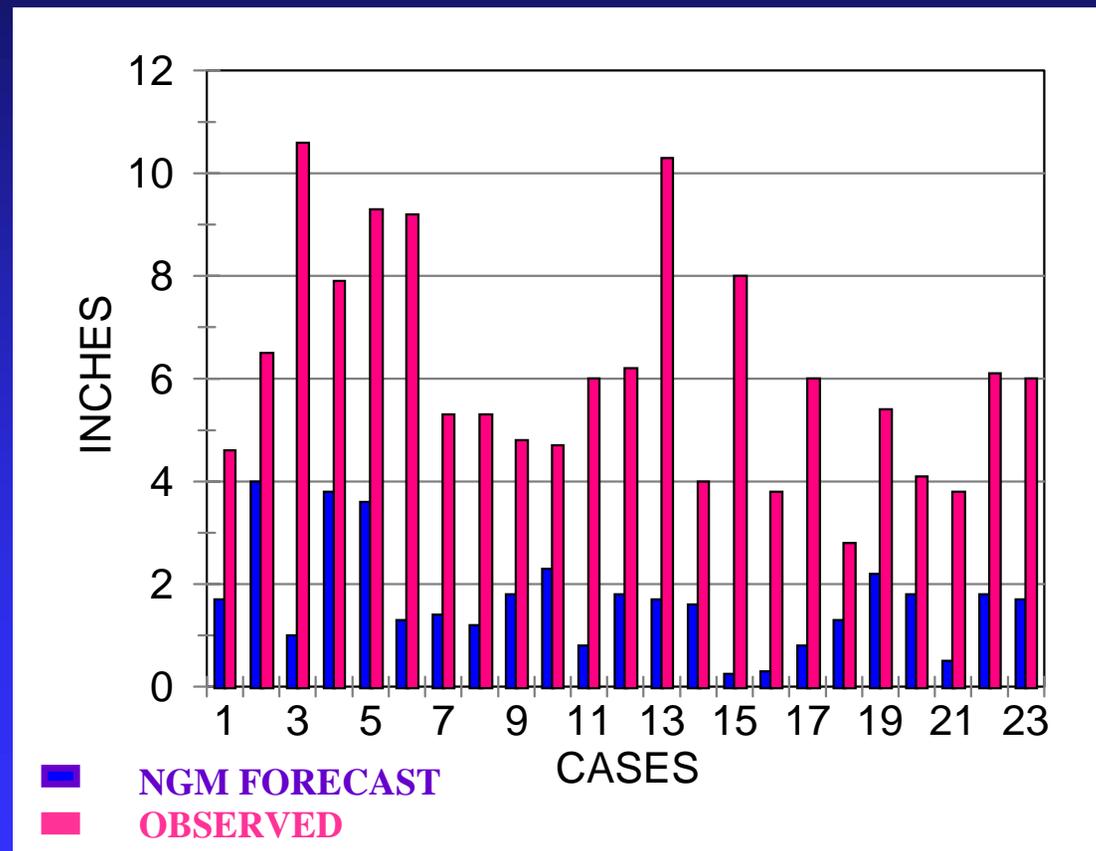
NGM .50" OR GREATER WINTER BIAS

HAS A HIGH BIAS ON THE EAST SIDE OF THE CASCADES AND SIERRA RANGES. TERRAIN IN WEST MUCH TOO SMOOTH.

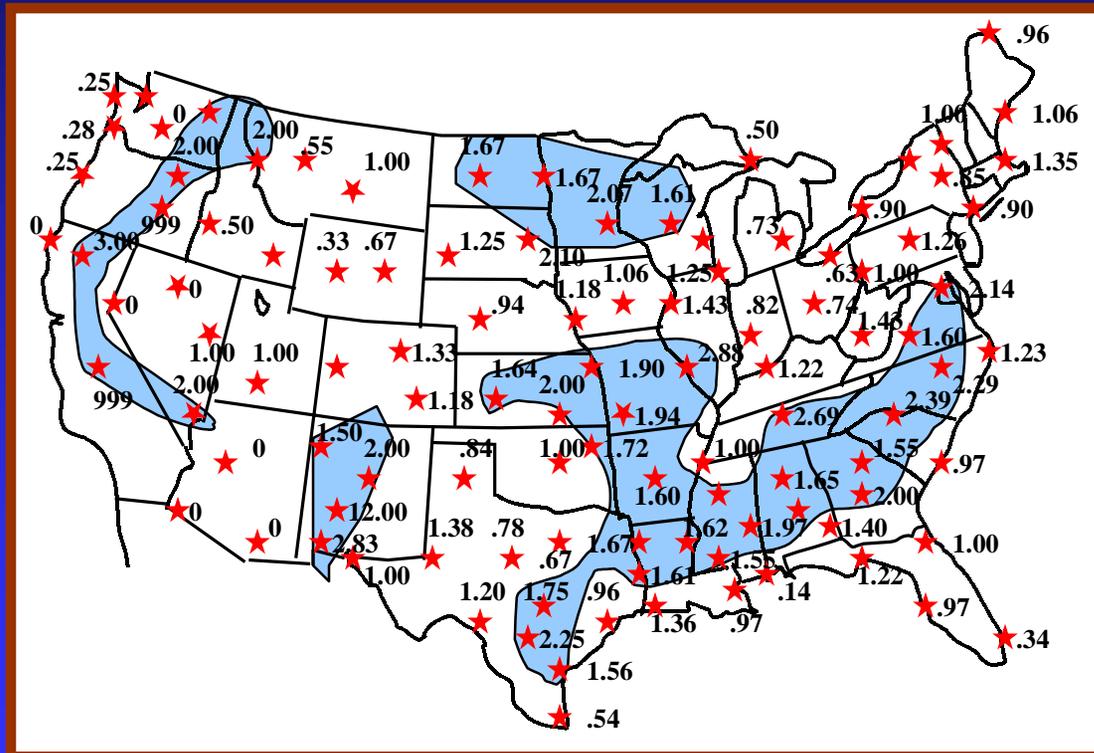


Note the low bias (yellow) across the Southeast, along Pacific Northwest Coast and the Southwest. The NGM underpredicts convection along cold fronts.

THE NGM ALMOST ALWAYS SIGNIFICANTLY UNDERPREDICTS THE MAXIMUM



NGM WARM SEASON BIAS FOR .50" OR GREATER AMOUNTS



FROM JUNKER ET AL., 1991

IN CONCLUSION

- THE ETA MODEL HAS BEEN A BIG STEP FORWARD.
 - ◆ MESOSCALE FEATURES ARE NOW SOMETIMES PREDICTED.
- QUANTITATIVE PRECIPITATION FORECASTS CONTINUE TO IMPROVE.
- BETTER VERIFICATION IS NEEDED OF OPERATIONAL MODELS. THE VERIFICATION NEEDS TO BE SHARED WITH FORECASTERS (MEDIA INCLUDED).
- THE MRF PERFORMANCE CHARACTERISTICS HAVE CHANGED SIGNIFICANTLY DURING THE PAST 2 YEARS.